

In re application of: THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

International Application No.: PCT/US03/39211

International Filing Date: 9 December 2003

Agent's Reference: 30794108WO01

Title: HIGHLY EFFICIENT GALLIUM NITRIDE BASED LIGHT EMITTING
DIODES VIA SURFACE ROUGHENING

AP3 Rec'd PCT/PTO 07 JUN 2005

AMENDMENT UNDER ARTICLE 19
BEFORE THE INTERNATIONAL BUREAU OF WIPO

VIA FACSIMILE
CONFIRMATION VIA FEDERAL EXPRESS

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20
SWITZERLAND

Dear Sir or Madam:

In response to the Search Report dated 26 May 2004, please amend the above-identified application as indicated below:

IN THE CLAIMS

It is requested that the claims of the above-referenced application be amended as provided on replacement pages 16-18 attached herewith. No new matter has been introduced by these amendments. The claims correspond to the current PCT claims as follows:

<u>Claims</u>	<u>Status</u>
1-2	Amended
3-7	Unchanged
8	Amended
9-14	Unchanged
15-16	Amended
17-18	Unchanged

REMARKS

In view of the above amendments, it is submitted that the claims are in a condition for a positive examination report. If this is not the case, the Examiner is encouraged to contact the Applicant's representative since a positive report is requested.

Please direct any inquiry to the below-signed attorney.

Respectfully submitted,

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ATTORNEYS FOR APPLICANT(S)

Date: 22 July 2004

By: 

George H. Gates

WHAT IS CLAIMED IS:

1. A gallium nitride (GaN) based light emitting diode (LED), wherein light is extracted through a nitrogen face (N-face) of the LED and a surface of the N-face is roughened.
5
2. The GaN LED of claim 1, wherein the surface of the N-face is roughened into one or more cones.
3. The GaN LED of claim 1, wherein the roughened surface reduces light
10 reflections occurring repeatedly inside the LED, and thus extracts more light out of the LED.
4. The GaN LED of claim 1, wherein the surface of the N-face is roughened by an anisotropic etching.
15
5. The GaN LED of claim 4, wherein the anisotropic etching is a dry etching.
6. The GaN LED of claim 4, wherein the anisotropic etching is a photo-
20 enhanced chemical (PEC) etching.
7. The GaN LED of claim 1, wherein the N-face is an n-type layer of the GaN LED.
- 25 8. The GaN LED of claim 1, wherein the N-face is prepared by a laser lift off (LLO) technique.
9. The GaN LED of claim 1, wherein the LED is grown on a c-plane GaN wafer and a gallium face (Ga-face) is a p-type layer.

10. The GaN LED of claim 1, wherein the LED is comprised of an n-type electrode, n-type layer, active region, p-type layer and p-type electrode.

5 11. The GaN LED of claim 10, wherein the n-type layer, active region and p-type layer are each comprised of a (B, Al, Ga, In)N alloy.

12. The GaN LED of claim 10, wherein the p-type electrode has a property of high reflection to decrease light absorption and to increase light reflection toward
10 the surface of the n-type layer.

13. The GaN LED of claim 10, wherein the LED includes a current-blocking layer aligned under the n-type electrode to keep the current from concentrating below the n-type electrode, so that absorption of light emission under
15 the n-type electrode can be avoided and extraction efficiency can be increased.

14. The GaN LED of claim 10, wherein the LED includes a current-confining frame made of an insulator to restrain leakage current through the sidewalls of the LED without significantly decreasing an emitting area.
20

15. The GaN LED of claim 2, wherein the roughened surface is comprised of a plurality of hexagonal shaped cones that have an angle equal to or smaller than:

$$2 \sin^{-1}(n_{air} / n_s) \approx 47.2^\circ$$

25

for GaN, where n_{air} is a refractive index of air and n_s is a refractive index of GaN.

16. The GaN LED of claim 2, wherein the roughened surface is comprised of a plurality of hexagonal shaped cones that have an angle equal to or smaller than:

$$2 \sin^{-1}(n_{enc} / n_s)$$

5 for epoxy, where n_{enc} is a refractive index of epoxy and n_s is a refractive index of GaN.

17. A method of creating a gallium nitride (GaN) based light emitting diode (LED), wherein light is extracted through a nitrogen face (N-face) of the LED,
10 comprising:

roughening a surface of the N-face into one or more cones.

18. A light emitting diode (LED) comprised of an n-type electrode, n-type layer, active region, p-type layer and p-type electrode, wherein a surface of the n-type
15 layer is roughened by an anisotropic etching into one or more cones and light is extracted through the roughened surface of the n-type layer.

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● Documents Transmitted:

- (1) Letter re Amendment Under Article 19 (2pp); and
- (2) Replacement Claim pages 16-18.